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HOW GREENWAYS WORK

A Handbook on Ecology

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HOW GREENWAYS WORK

A Handbook on Ecology

Second Edition

Jonathan M. Labaree

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I

Acknowledgments

This handbook draws upon *The Ecology of Greenways*, edited by Daniel S. Smith and Paul A. Hellmund (to be published in 1993 by the University of Minnesota Press). *The Ecology of Greenways* includes sections written by experts in the fields of landscape ecology, water resources, wildlife corridors, recreational design, site design, and design and management techniques. Specific attribution for subject areas is as follows:

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While *How Greenways Work* serves as an introduction to basic ecological principles that apply to greenways, *The Ecology of Greenways* is a more detailed and technical volume.

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Preface

This is a handbook for those private citizens and public officials all over America who are working to create outdoor recreation opportunities and protect wildlife and our environment by establishing corridors of open space called greenways.

Greenways connect. They tie together people, parks, historic sites, and natural areas. They follow streams and rivers, ridgelines, abandoned rail lines, hedgerows, canals, and other transportation corridors. All are unique, created through local initiative and reflecting a consensus of community needs and concerns.

Preserving and restoring the natural world, especially near where we live and work, is one of the nation's most important conservation goals — and providing greenways may be one of the most beneficial and effective conservation strategies to accomplish it. To do this job effectively, we need to know about specific functions and values, and the respective planning and management strategies to implement them.

Through the emerging science of landscape ecology, we are learning more and more about the importance of the "linkage" that greenways provide in maintaining and restoring ecological processes and in maintaining the health of a landscape. Unfortunately much more research needs to be done before we can develop explicit criteria and strategies to protect the ecological functioning of each kind of corridor and environment for the nation's tremendously varied landscape and ecosystems.

This handbook is intended as a guide and introduction to the subject of using greenway corridors in enhancing ecological process.

Let us know how well it worked, your successes (and failure, if instructive!), new sources of information, and ideas. We will share them in an update. Good luck.

William T. Spitzer
Chief, Recreation Resources Assistance Division
National Park Service

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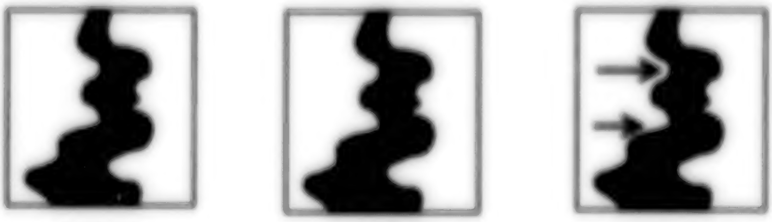
Introduction

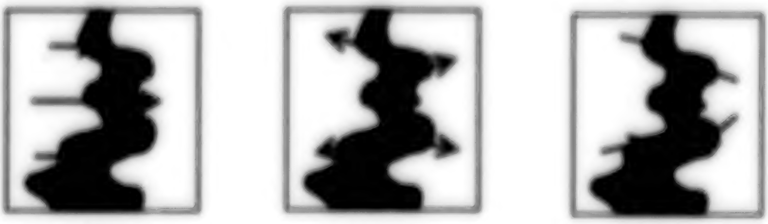
The purpose of this handbook is to serve as an introduction into ways in which we can design and manage greenways to fulfill their ecological potential. Greenways offer a whole range of benefits beyond traditional ones — open space and recreation — that are making greenways a popular conservation strategy. They can also meet very important ecological needs. Ensuring that a greenway fulfills its ecological potential rests upon understanding how a landscape functions and the role greenways can play in that functioning.

In this handbook, "landscape" matches some of the meaning of "ecosystem" — an area subject to a specific set of environmental conditions and characterized by a distinct land cover or mixture of land covers — but specifically includes the presence of people. Thus, a road is as much part of the landscape as a river.

When we look out over what appears to us as a distinct piece of nature, such as an alpine meadow, we must realize that our view is but one of many. We cannot see groundwater flowing out of the surrounding wooded slopes bringing nutrients, minerals, and microorganisms into the meadow's soil. We do not notice the mice and ants constantly moving seeds within and beyond the meadow's edge. The hawk soaring overhead does not confine itself to the field, but hunts and nests elsewhere. The glacier that formed the valley, depositing sediment and creating ancient lakes, has long since retreated.

So much movement and activity should convince us to consider the meadow as an intricate series of connections


habitat conduit barrier


filter source sink

These symbols, representing ecological functions of greenways, appear frequently in the text.

with its surroundings rather than an isolated patch of grass and flowers. A change in perspective that will help us to grasp ecological functioning is to see nature as a system of interconnected, interdependent, and ever-changing parts.

"Part" can refer to any number of elements within a landscape: a river, mountain, field, glacier, lake, barrier island, forest. Basing land conservation on ecological criteria means protecting not just these physical elements, but their interactions, or functions, as well. Greenways, being linear, are best suited to protect parts of the natural landscape which are also linear. These linear landscape elements are called environmental corridors. The challenge for conservationists is to design greenways so they protect corridors and their functions.

For the purposes of this handbook, 'greenway' refers to a linear feature created by people while 'corridor' is a linear feature that exists naturally.

Of the many functions of corridors, this handbook focuses primarily on those functions related to wildlife and to water resources (elaborated in Chapter III). Before diving into specifics, however, it is important to understand the way in which our modifications to the environment influences natural balances (covered in Chapter I) and the ecological functions of corridors that we hope to maintain when creating greenways (Chapter II).

There is much more to establishing a greenway than locating it properly in the landscape; managers will be continually challenged in their effort to maintain their greenway's ecological functioning (such issues are the subject of Chapter IV). While this handbook emphasizes ecology, other issues are important to people involved in greenway projects: designing the greenway so it is a pleasant place to be; avoiding conflicts between different uses; or capitalizing on economic benefits that a greenway can bring to a community. There are references throughout the text to other publications which deal with these topics in greater depth.

CHAPTER I

Ecological Impacts of Development

An underlying principle of conservation is that utilizing natural resources does not, in itself, pose a threat to the environment. It is the manner in which we do it that dictates whether our activities are detrimental or benign. Our modifications have created new patterns in the landscape which can threaten ecological functioning. Dramatic shifts in the ratio between natural and developed land has lead to:

- loss of natural space;
- fragmentation of natural spaces;
- degradation of water resources; and
- decreased ability for nature to respond to change.

Loss of natural space

Developing land for human needs reduces the amount of natural space. As natural space diminishes, so does habitat diversity — the great variety of forests, prairies, bogs, and deserts which exist in nature. The result is both a decline in the number of species and fewer individuals of those species which do survive. Converting midwestern short- and tallgrass prairies over to agriculture, for example, has lead to a decline in native grass and wildflower species and in animals adapted to prairie habitat. We have substituted native species with ones which better meet our needs — cattle, corn, wheat, pigs. While this has had advantages for society, it has upset the natural balance of those ecosystems. We are generally able to sustain our agricultural

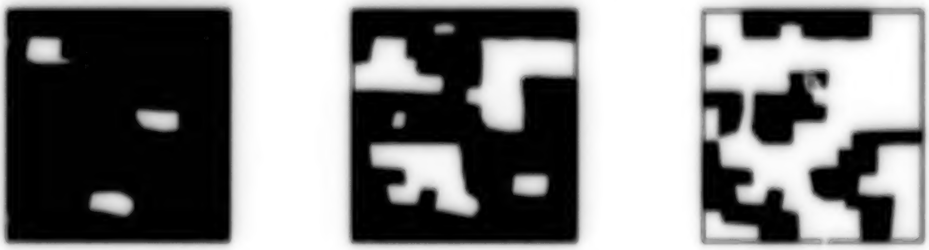


Figure 1. Time series of fragmentation. Fragmentation becomes apparent in this hypothetical sequence of a landscape being converted to agriculture. The landscape has little natural land remaining (shaded areas) in the final frame. The patches that remain are small and isolated.

systems only by replenishing fields with fertilizers and groundwater and by protecting them from pests with chemicals.

Fragmentation of natural spaces

A "patch" is an area of uniform habitat which is surrounded by significantly different land, such as a woodlot among cornfields.

Development has an indirect impact on land it leaves untouched. As we convert land, we fragment it into smaller and more isolated patches of natural space (see Figure 1). The new pattern that we have created on the landscape greatly alters the way in which natural systems function. Wildlife and flora populations have evolved, and continue to evolve, in conjunction with their surroundings. They have developed strategies to exploit their environment in order to fulfill basic life needs. Different species utilize different habitats. Any change in their habitat will affect their ability to survive. Two major reasons why fragmentation is destructive are increase in edge habitat and greater isolation between patches.

"Habitat" refers to those parts of a landscape which an animal species uses for feeding, breeding, movement, and shelter. A plant's habitat is often determined by environmental factors such as temperature, precipitation, and geologic formations.

Edge habitat — Edge habitat is an area of transition between two types of land cover. Edges exist throughout nature in many forms and are often areas of high biological diversity because two or more natural communities come together and influence each other. Plants and animals which live in each community utilize the edge as does a distinct set of species specifically adapted to ecological edges. Edge habitat that results from human activity can be disruptive. While some species are adapted to edge habitat, there are many species which require interior spaces, shielded from the influence of surrounding lands. Fragmentation changes the natural balance between edge and interior. Indeed, heavily fragmented landscapes may not have any interior habitat at all.

In *Ecology of Greenways*, Reed Noss defines a population as "a group of individuals of the same species living within a geographic area restricted enough that any member of the population can potentially mate with any other member of the opposite sex."

Isolation of patches — In fragmented landscapes, development has left many wildlife populations isolated from needed habitat and other individuals of their species. Some species are not sensitive to humans and survive quite well in our presence. Other species, however, will not come near even a modest development or fly across a cultivated field. Although natural land may still exist in fragmented landscapes, species sensitive to people cannot move freely in order to utilize it. This not only cuts individuals off from habitat, it makes it harder for them to sustain their populations by creating barriers between potential mates.

Degradation of water resources

Wetlands and lands along rivers perform a variety of critical functions related to water resources: controlling floods, trapping sediments, filtering out toxins and excess nutrients, and supporting rich assortments of wildlife and plant species. These same areas are often favored for development because they are flat, arable, or have high residential value. Developing wetlands and riparian zones reduces their capacity to fulfill their functions and threatens the health of the environment.

"Riparian zone" refers to the area surrounding a stream or river (illustrated in Figure 10 on page 23) and is composed of the stream, its flat flood plain (the region in which the stream meanders — also the area most likely to be inundated during a flood), the steeper banks, and the uplands which are often wooded.

Decreased ability for nature to respond to change

Species naturally respond to changing conditions both in the climate and in their predators and prey. Development has decreased nature's ability to respond to these changes in two fundamental ways: reducing genetic diversity and hindering wildlife movement. As populations of plant and animal species decline, their genetic diversity also declines, diminishing their ability to adapt to long-term change. In addition to genetic alterations, plants and animals respond to their changing environment through movement. Animals move in response to events such as wildfires or hurricanes. As climate changes, both plants and animals move to stay in environments to which they are adapted. Fragmentation hinders this movement. Pollution may be increasing the rate of change beyond nature's ability to respond.

Ecological Functions of Corridors

This chapter introduces some basic concepts which are important for understanding the role which corridors, and hence greenways, play in the landscape.

Nature is a series of interactions among plants, animals, and even air, soil, and water. A healthy environment depends upon keeping those interactions intact. The threats described in the previous chapter result from alterations we have made in the landscape that hinder natural processes. The challenge for conservationists is to ensure that we orient future development in a way which sustains natural processes. Protecting environmental corridors through establishing and managing greenways represents one method (to be used in conjunction with other approaches) to safeguard vital ecological processes.

If we are to understand truly our impact on the landscape, we must learn to see it not as a bunch of independent pieces — a woodlot here, a river there, and a grassland yonder — but as intricately connected parts of a larger whole. Any given part of a landscape affects other parts. When designing a greenway, it is important to consider what impact it will have on natural processes. A greenway — like their natural counterparts, environmental corridors — can operate in six basic ways:

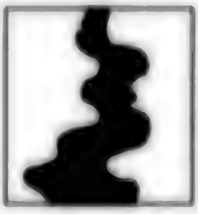
- as **habitat** for plant and animal communities;
- as a **conduit** for plants, animals, water, sediment, and chemicals;
- as a **barrier** preventing movement;
- as a **filter** allowing some things to pass while inhibiting others;
- as a **source** for animals or seeds which move to other parts of the landscape; and
- as a **sink** for trapping sediment, toxins, or nutrients.

Since it may not be possible, or desirable, to design a greenway to fulfill all six functions, planners should identify which ones are most important to the site. For example, in a heavily developed area, a greenway can offer scarce *habitat*.

Ecological Functions of Corridors

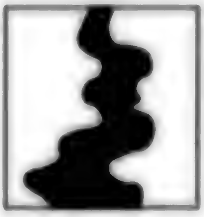
Severely fragmented landscapes would benefit from a greenway designed to be a *conduit* allowing animals to reach isolated protected areas. A greenway which is along a river should be planned to *filter* excess nutrients from surrounding lands (in which case it also acts as a *barrier* preventing movement of sediments and a *sink* storing them). One proposed along an abandoned rail bed in the midwest can act as a *source* of native prairie grasses.

Greenways as habitat

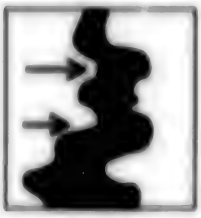


A species' habitat may include many different types of vegetation and geography, such as wetlands, upland forests, and fields. A greenway's ability to provide habitat will depend upon its size, location, and the needs of native species. A greenway that is 200 feet wide will generally contain habitat for fewer species than one in a similar location that is half a mile wide. A 200-foot-wide greenway along a river, however, that includes a variety of vegetation, may provide habitat for as many species as a wider one in a setting with less natural variation. Some species require more natural area than others. A 200-foot-wide greenway, therefore, may provide plenty of habitat for salamanders, beetles, and frogs, but very little for bears, eagles, and elk.

Greenways as conduit

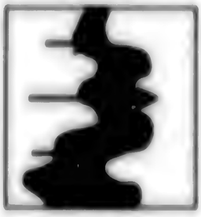


Conduits are areas in the landscape along which water, animals, plants, and people move. A river is among the most obvious examples of a conduit. Water carries sediment, nutrients, leaves, insects, bacteria, and plankton along with it. Acting as a conduit to connect otherwise isolated parts of the landscape is an important function of greenways. Such connections will allow animals to reach necessary elements of their habitat. As animals or water move along a greenway conduit, seeds do as well, thus aiding in plant dispersal.



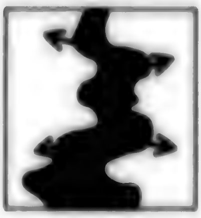
Greenways as barrier

While a greenway may be a conduit to some things, it presents a barrier to others. Again, a river serves as an example. Small animals, such as mice, may be unable to cross a river. Or its moist habitat may be inhospitable to creatures that prefer drier surroundings. Even very narrow corridors, such as hedgerows, can present a physical barrier of impassable habitat for some species.



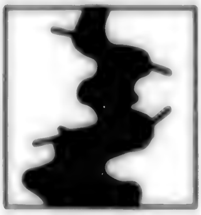
Greenways as filter

A filter prevents the passage of some things but allows the passage of others. Filtering can occur in a greenway either perpendicular to its axis or along its length. Large animals, able to traverse a river, for example, can pass across a riparian greenway, but small ones may not. Similarly, some animals may be able to move along the entire length of a greenway, while others may fall victim to predators or find the habitat inhospitable. The next chapter deals extensively with a greenway's potential to filter sediments and nutrients from surface and groundwater.



Greenways as source

A greenway may act as a source, providing surrounding land with a variety of things. A riparian greenway may be the only source of water in an otherwise arid landscape. In human-dominated areas, even narrow strips of relatively undisturbed land, such as hedgerows or steep slopes, may be a source of seeds of either native or non-native species.



Greenways as sink

A greenway acts as an ecological sink when something moves into it but does not travel back out into the surrounding land. Perhaps the most significant way a greenway can be a sink is by trapping sediments and nutrients carried in surface and groundwater. This function is, however, dependent upon a specific time frame because sediments may eventually wash downstream during a dramatic flood, or nutrients absorbed by vegetation will re-enter the soil and atmosphere when the plant decays.

CHAPTER III

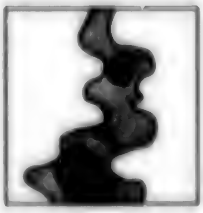
Greenways, Wildlife, and Water Resources

This chapter outlines some possibilities and limitations involved in planning a greenway to fulfill the six ecological functions introduced in Chapter II.

Greenways and wildlife

The two major ecological functions that greenways can fulfill for wildlife are providing **habitat** and acting as **conduits**.

Greenways and wildlife — habitat



A greenway's potential to serve as habitat for native plant and animal species will depend upon its size and the condition of the surrounding land. Generally, the larger the greenway, the more species and individuals it will support. All habitat within a greenway, however, may not be suitable for some species because of edge effects.

"Edge effects" refers primarily to the impact that one type of habitat may have on its neighbor.

Edge effects are particularly acute where a cultivated field borders a native forest or woodlot. Increased light and wind at the forest's edge leads to drier soils, more light-favoring species, and more blowdowns. Species that are adapted to the moist soils and shady environment of the forest interior are unable to survive in edge habitat.

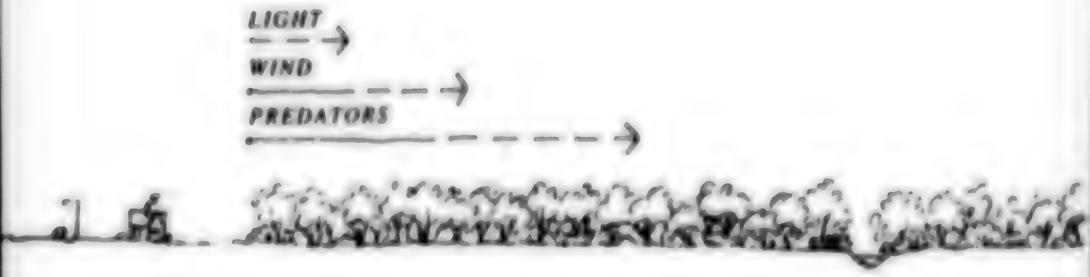


Figure 2. Edge effects. Increased light, wind, and predators characterize the edge of a forest where it borders a field. Each effect penetrates differently into the forest as indicated by the arrows.

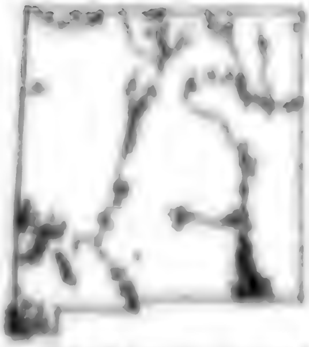


Figure 3. Location of rare and endangered species in New Mexico. The vast majority of rare and endangered species in New Mexico exist within or near riparian ecosystems. Thus greenways which afford protection to riparian zones will also house these species. (After a map in Mackintosh, G. ed. 1989. Preserving Communities and Corridors. Washington DC: Defenders of Wildlife.)

Not only are many species adapted to interior habitat, but they are not adapted to the presence of species which inhabit edge. More edge increases the ability of non-interior species, such as the common grackle or brown-headed cowbird, to feed on interior ones or to compete with them for nesting sites or food. Edge species also introduce a new set of diseases to which interior species may be vulnerable.

Vegetation and wildlife react to the effects of edge differently. While changes in vegetation at edges, due largely to increased light and wind, may extend 50 to 100 feet into a temperate forest, researchers have noted adverse effects to wildlife as deep as 1,000 to 2,000 feet from a forest's edge (Wilcove, *et al.*, 1986). This difference stems, at least in part, from predators venturing into interior habitat (see Figure 4).

Because the problem of edge effect is so acute, many greenways will be most useful for animals whose natural habitat is linear. River systems are a good example. Riparian ecosystems support high densities of vertebrates. They often contain more species and more individuals than does surrounding land. Seventy-five percent of the vertebrates in Oregon and Washington's Blue Mountains depend upon, or prefer, riparian habitat (Thomas *et al.*, 1979). In arid and semi-arid lands, river corridors are extremely important. In Arizona and New Mexico, eighty percent of the vertebrate species depend upon riparian areas during at least part of their life (see Figure 3) (Johnson, 1989).

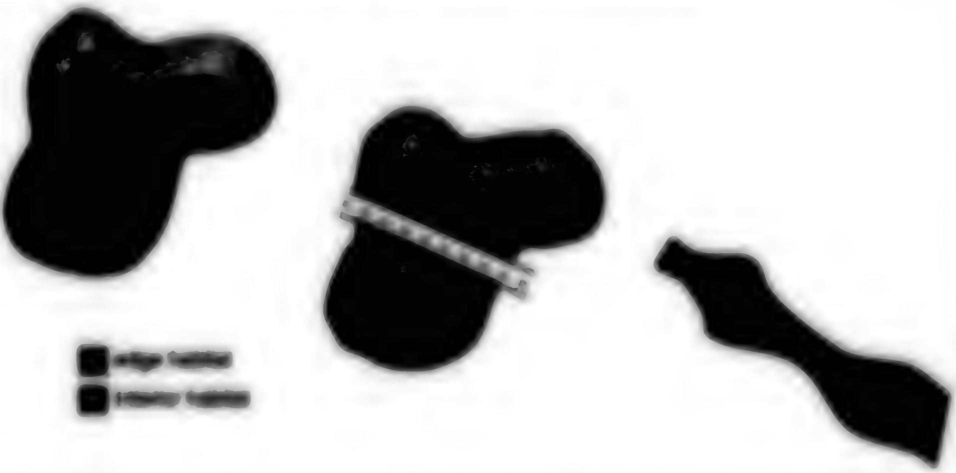


Figure 4. Effects of fragmentation and narrowness on interior habitat. The drawing at left shows a natural patch of land with edge effects penetrating around its perimeter. In the middle, a road has dissected the same patch, greatly reducing the amount of interior habitat. A greenway, right, will often have little interior habitat because it is too narrow to overcome the effects of edge.

Figure 2. Hedgerows in agricultural landscapes. Many agricultural landscapes have rows of shrubs or trees along the edges of fields or planted as protection for topsoil and livestock.

In agricultural landscapes, hedgerows, shelterbelts, and greenways often may be the only wooded or shrubby habitat. Rows of shelter trees provide habitat for birds in Minnesota (Yahner, 1982). In Great Britain where agriculture dominates much of the landscape, hedgerows are critical breeding habitat for many species of rodents, birds, and insects (Way, 1977). In a landscape with little natural land a greenway—no matter how narrow—will be beneficial.

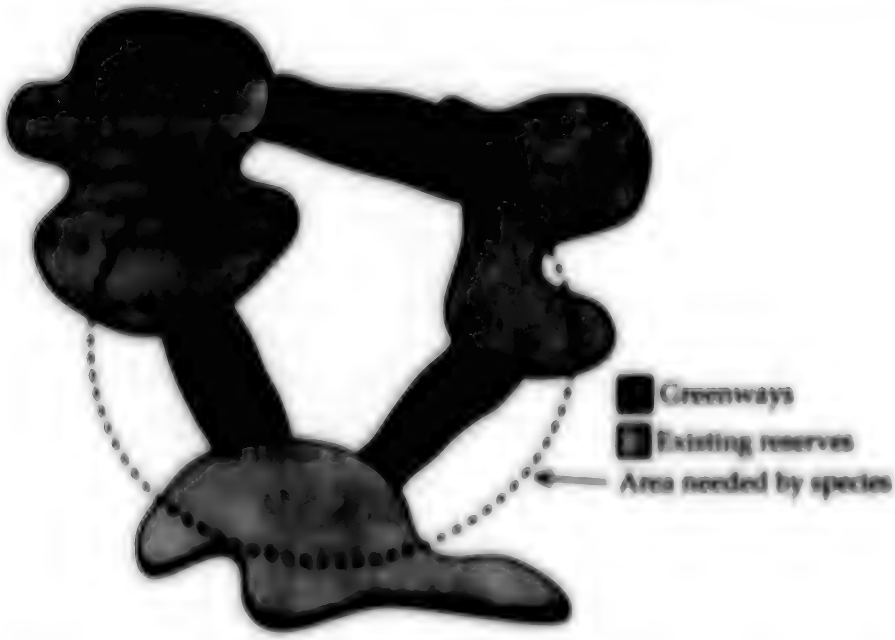


Figure 6. How greenways can increase the effective size of existing reserves. The dotted circle represents a theoretical amount of land a species needs. Any one of the reserves is not large enough. If greenways connect the reserves together, there may be enough protected land for the species.

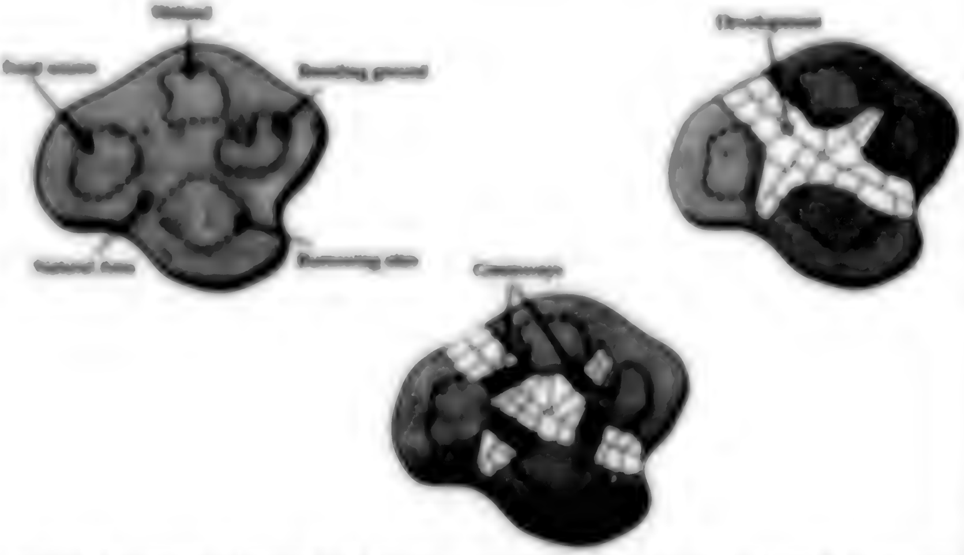
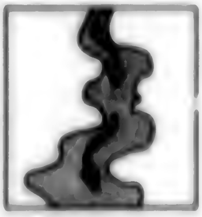


Figure 7. Isolation from habitat. The figure in the upper left depicts a theoretical patch of natural land interspersed with habitats (dotted areas) that a species such as raccoon might use regularly. In the upper right, a development has left important habitat intact, but has prevented animals from utilizing it. Connecting habitat patches with greenways, as in the bottom figure, gives these species the opportunity to use all the undeveloped landscape.



Greenways and wildlife — conduit

A wildlife population has two basic requirements for long-term survival: enough natural space to satisfy life needs of individuals and a population which can sustain itself. Fragmentation threatens many wildlife species' ability to meet both those requirements. Properly designed and managed greenways, however, can help wildlife overcome effects of fragmentation by:

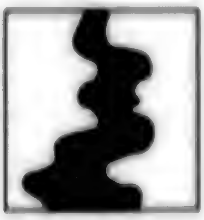
- increasing the effective size of protected areas;
- creating access to different habitats; and
- connecting wildlife populations.

Increasing effective size of protected areas — Wildlife species require a certain amount of habitat to survive — they need to roam in order to breed and to find food and nesting, den, or burrow sites. Generally, the larger the animal, the greater its home range. An animal's home range will also depend upon its trophic level — how high on the food chain it resides. Predator species usually have larger home ranges than herbivores of equivalent size. Since a wildlife population needs to be of a certain size to remain healthy, the amount of natural land it requires is proportional to the home range of its individuals.

"Home range" is the total area an individual of a species uses to fulfill its life needs.

In fragmented landscapes, the needed amount of natural land may exist but be divided into isolated pieces. If greenways connect smaller parcels, animals can move among them, utilizing their total area, not just that of an individual patch. The "effective size" of each patch thus approaches the total size of all the connected natural areas. In this way, greenways can increase the effective size of a series of protected areas (see Figure 6).

Creating access to different habitats — Natural space alone is not enough to ensure wildlife conservation — diversity of habitat types is also critical. Species such as raccoon, white-tailed deer, river otter, and gray fox use more than one kind of habitat (see Figure 7). Thus, a patch of natural land may correspond to a species' home range, but might not contain all the habitats the species needs. Patterns of development often create barriers between necessary habitats, hampering wildlife's efforts to survive. Connecting patches which support different habitats with greenways can greatly enhance an individual's opportunity to reach the diversity of habitats it needs to survive.



Connecting wildlife populations —
The same forces which separate individuals from needed natural lands can also prevent them from finding other members of their species. As forest interior shrinks, the distance between members of a species increases. Intervening land becomes a barrier if it harbors predators, or if species are naturally unwilling to traverse it. Isolation from others in their species affects wildlife populations in two ways: demographically and genetically.

Scientists use the term "demographic" to refer mostly to birth and death rates. For the purposes of this handbook, the term describes other events which influence the size of a population.

Demographic effects of isolation will occasionally lead wildlife populations living in small patches of forest (or prairie, wetlands, desert) to die off in that immediate area. Causes include disease, disturbance, increase in predators or competitors, and fluctuations in birth and death rates. Small wildlife populations are more likely to succumb to these random events than large ones. These localized extinctions occur naturally. If a population of white-footed mice, say, dies off in a small patch of woodland, individuals from a nearby patch will recolonize the now vacant woodlot.

By creating small and isolated patches of natural space, fragmentation can divide a once large wildlife population into smaller, more vulnerable populations. Fragmentation also makes it more difficult for members of other populations to recolonize vacated habitat. While greenways may not make demographically driven local extinctions any less likely, they can provide conduits to make recolonization by other populations easier (see Figure 8).

Wildlife populations can be susceptible to a number of genetic effects from isolation. Close relatives are more likely to mate as populations become isolated. Common results of breeding between relatives are increased juvenile mortality, decreased fertility, and reduced overall ability of a species to survive. Small populations are likely to become more genetically similar — the potential for change and adaptation is lost. A species may lose a rare genetic trait which could help it survive under different circumstances.

In most species, some individuals will disperse away from their natal population to ensure genetic diversity. In fragmented landscapes, greenways can play an important role in making such dispersal possible. Given the opportunity to fulfill their natural tendencies to disperse, individuals will bring new genes to a population with declining genetic diversity. A greenway can provide that opportunity.

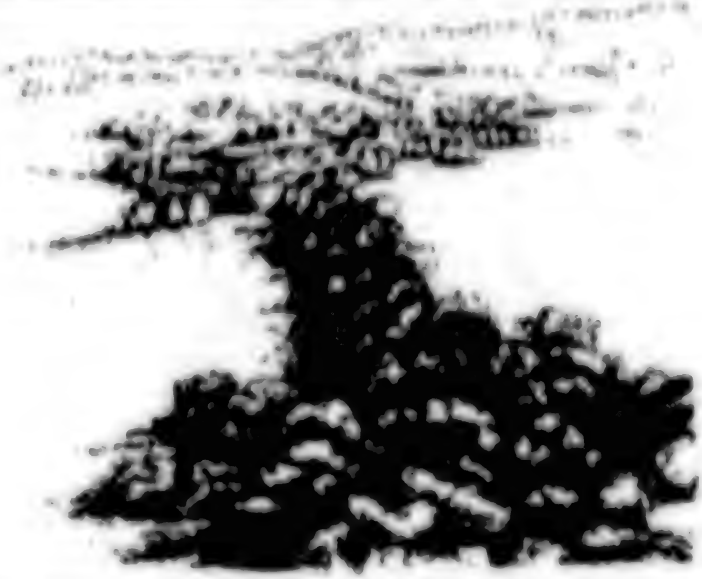


Figure 8. Providing access to other populations. The illustration shows two patches of forest connected by a corridor. If a population dies out in one patch, then individuals can make their way from the other and recolonize it.

Adapting to long-term changes — As the climate changes, whether due to human influence or not, plants and animals will have to disperse and find areas to which they have adapted. While a single, locally oriented greenway may help connect two populations of a wildlife species, it is unlikely to provide the substantial linkages necessary for plant and animal species to respond to long-term climatic changes. When possible, cooperating with neighboring towns or jurisdictions could ensure that greenways join up at municipal boundaries, thereby establishing broad-scale connections extending beyond the borders of a given town.

Ensuring that greenways are effective conduits

A greenway will only act as a conduit for wildlife if individuals are willing and able to travel along it. Width and quality play major roles in determining whether animals will use a greenway for movement. A greenway must also offer a continuous link with as little disturbance from roads and other development as possible.

How wide? There is not a magic width at which a greenway will begin to act as a conduit. As a general rule, wildlife ecologists recommend that there be a one-to-one ratio between edge and interior habitat in a conduit greenway. Drawing on figures presented on page 12 relating to edge effects, a greenway would need to be 400 feet wide to balance 200 feet of edge habitat (100 feet of edge on either side) with 200 feet of interior habitat.

Many species use riparian corridors for movement. Thus, establishing a greenway in a riparian zone will offer a good opportunity to protect its conduit function. Proper width of a riparian movement greenway depends largely on the nature of the riparian zone. Such a greenway should be wide enough to include the entire riparian zone (see Figure 10, page 23) on at least one side of the stream and interior habitat in associated uplands. Ideally, this interior habitat would exist in a one-to-one ratio with edge habitat.

Exotic species, discussed in more detail in Chapter IV, are those which are not naturally part of an ecosystem but which have arrived there, often with the aid of people, and survived in their new environment. Other terms for exotic species are non-native or introduced species.

Species sensitive to humans will need wider greenways for movement than will more tolerant ones. Therefore, another factor determining width for a greenway is the species most likely to use it. Large predator species may require greenway widths measured in miles. Other species such as the blue jay will travel along a narrow hedgerow (although capable of flying across open lands, jays, like many birds, prefer to remain in woodlands).

Quality of the greenway is as important as width. Not all species should be able to move along a corridor. Exotic species may move along corridors creating competition for native ones. Maintaining a greenway with native plant species and minimizing the amount of edge habitat will help ensure that exotic species will not displace desirable ones.

The quality of surrounding land will also influence how effectively a greenway will function as a conduit. The greater level of development in lands adjacent to the greenway, the wider the greenway will need to be to overcome disturbance from noise, people, and pets (dogs and cats are very efficient predators).

Guidelines for designing greenways to provide habitat and act as conduits

Habitat:

Identify the needs of the most sensitive species for which the greenway is to provide habitat. Greenway managers should be particularly aware of species which are sensitive to edge effects because greenways will generally contain a lot of edge habitat.

For the most part, greenways will not, by themselves, provide good habitat. Therefore, do not allow greenway projects to proceed at the expense of other initiatives which will provide habitat, such as large reserves.

Conduits:

Concentrate on matching natural characteristics of the landscape — both in terms of species composition and connecting patches of habitat which were originally connected but human development has left isolated.

Ensure that the greenway meets the movement needs of the species which are most sensitive to people. It may be necessary to build tunnels under roads or include specific habitat which a particular species requires.

General requirements:

Undertake a natural resource inventory before planning and designing a greenway. The inventory will identify the area's native mixture of species and special plants, animals, and habitats.

Follow the inventory with a review of research done on the local landscape. Such a review may reveal studies concerning conservation needs of native plant and animal species or local impacts of edge effects.

Sources of information:

For specific information about native plant and animal species, conservation biologists at a nearby college or university, U.S. Fish and Wildlife Service biologists, and agricultural extension agents can be of great assistance.

Harris, L.D. 1984. *The Fragmented Forest: Island biogeography theory and the preservation of biotic diversity.* Chicago: University of Chicago Press.

Saunders, D. A., R. J. Hobbs and C. R. Margules. 1991. "Biological consequences of ecosystem fragmentation: A review." *Conservation Biology.* 5 (1): 18-32.

Soulé, M. E. 1991. "Land use planning and wildlife maintenance: Guidelines for conserving wildlife in an urban landscape." *APA Journal.* 57 (3): 313-323.

The journal *Conservation Biology*, published by the Society of Conservation Biology, is an excellent source of contemporary scientific research relating to conservation.

Santa Monica Mountains Case Study

The Santa Monica Mountains, outside of Los Angeles in southern California, offer an example of how fragmentation threatens wildlife and how greenways can alleviate the problem by acting as conduits.

The Santa Monica Mountains lie at the southern tip of a mountain range which spreads northward through the Simi Hills to the Santa Susana Mountains and finally into the vast mountain ranges of Los Padres and Angeles National Forests (which are off the map to the north). The mountains originally harbored an uninterrupted band of mountainous habitat. Westward expansion, however, has created two significant divisions where freeways cut across the ranges — the *Simi* Valley Freeway (Rt. 118) and the Ventura Freeway (Rt. 101). These highways have effectively isolated the Santa Monicas and the Simi Hills from the Santa Susana Mountains and the two National Forests.

The mountain range supports a wide diversity of wildlife species. Although large areas of mountain habitat remain in the Santa Monicas and Simi Hills, the remnant patches are probably too small to sustain some wildlife populations. For example, scientists estimate that there are only eight mountain lions in the Santa Monica Mountains. A population which is that small is very likely to succumb to the isolation effects discussed on page 16. Bobcat, grey fox, and badgers, while not currently in such low numbers, may also disappear from the Santa Monica Mountains.

Preventing the loss of these and other wildlife species will depend upon overcoming the effects of fragmentation and allowing the now-divided mountain range to function as a whole. The National Park Service (which runs a National Recreation Area in the Santa Monicas) has joined efforts with the Santa Monica Mountains Conservancy (a state-authorized organization) to create corridors connecting the Santa Monica Mountains, the Simi Hills, and the Santa Susana Mountains. With animals able to move the length of the mountain range, the Los Padres and Angeles National Forests will be a source of individuals for declining wildlife populations in the smaller reserves to the south.

The plan for restoring wildlife movement in the range has two focuses — protecting land along which wildlife can move and building tunnels under the freeways. A study of an existing underpass (intended for horseback riding) has demonstrated that mule deer, coyote, bobcat, grey fox, and possibly mountain lion used the tunnel. An underpass designed expressly for wildlife movement is likely to be even more effective.

In an effort to ensure that wildlife species would move along the corridors, the planners developed a list of guidelines based on studies about native wildlife populations and their territorial needs and movement patterns. The guidelines emphasize protecting natural habitat and traditional movement routes. The designers paid particular attention to minimizing present and future contact with people.

Priorities for conservation will continue to be a subject of debate among conservationists. Clearly there is a need to protect areas which are large enough to sustain species such as mountain lions and grey fox. This case, however, makes a strong argument for targeting small tracts of land which will take advantage of existing protected areas. Connecting the Santa Monica Mountains and the Simi Hills with the Santa Susana Mountains and the Los Padres and Angeles National Forests increases the effective size of the smaller reserves and gives wildlife the opportunity to replenish isolated populations.

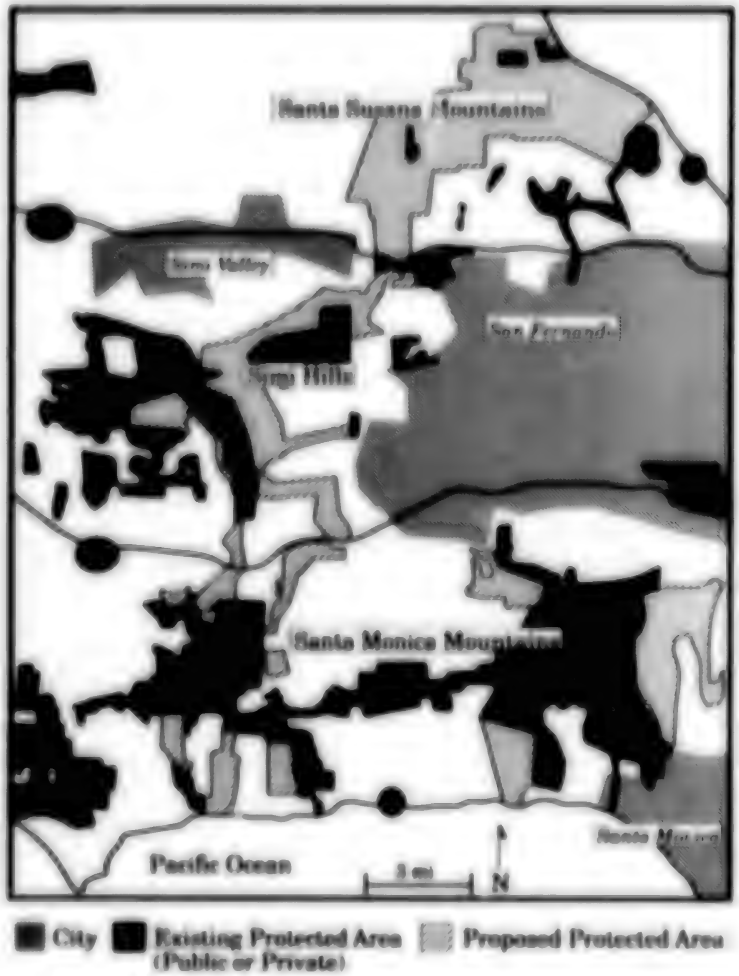


Figure 8. Map of Santa Monica Mountains proposed wildlife movement corridor system.

Greenways and water resources

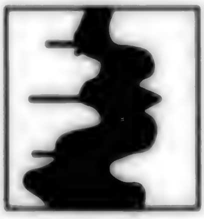
Many of the existing and proposed greenways in the United States at some point follow the course of a river. As such, they offer a terrific opportunity to protect riparian ecosystems and the variety of ecological roles they perform. By acting as a sink, a filter, a barrier, and a source, a greenway can maintain the following functions which are associated with riparian zones:

- flow moderation;
- nutrient and sediment filtration;
- temperature regulation;
- bank stabilization; and
- food and habitat provision for aquatic communities.

Flow moderation

Riparian zones moderate water flow through the connected processes of physical resistance from vegetation, absorption of water into the soil, transpiration of water from plants, and groundwater discharge. When a stream floods, it overflows its banks and inundates the surrounding flat land, known as the flood plain. If that area is nothing but farmland or pavement, the river will maintain much of its velocity. If, on the other hand, the flood plain is covered with its natural vegetation, it will act as a sink, absorbing the flooding river's energy and much of its water (at least temporarily). Riparian plants will slow the flood down as stems and trunks block the water's progress. As the stream's velocity subsides, more water seeps into the flood plain's rich soils. This water is either released into the atmosphere by plants, evaporated from the soil when the flood subsides, or discharged slowly as it makes its way through the ground to the stream again.

Nutrient and sediment filtration



Riparian zones filter out nutrients and other harmful chemicals from surrounding land uses. A common problem in developed areas is increased nutrient load in rivers from industrial, residential, and agricultural areas. Riparian systems can reduce the nutrients in water coming from surrounding lands. A riparian zone's ability to filter a given nutrient depends upon such factors as its vegetation, slope, the initial concentration of the nutrient, and how the nutrient is moving. Nutrients and toxins can be attached to

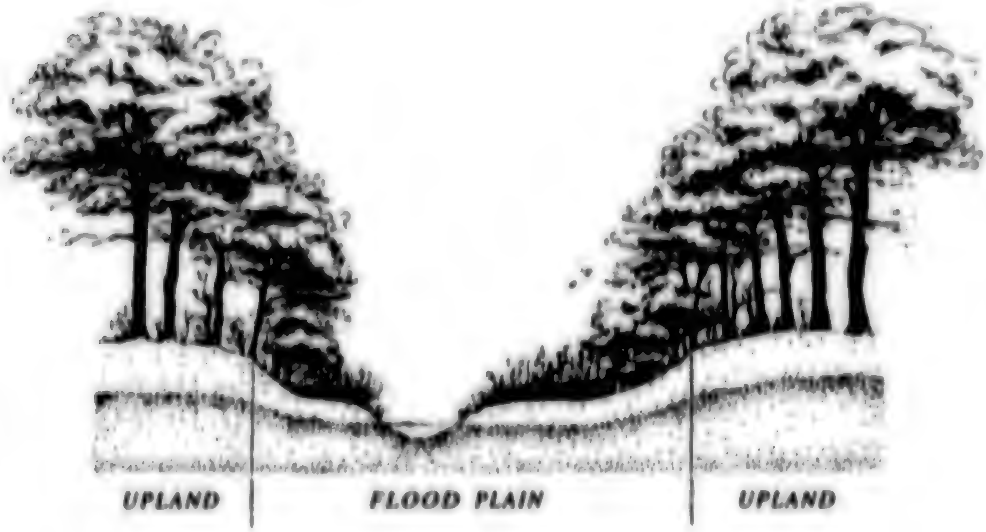


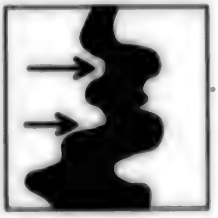
Figure 10. Delineation and composition of the riparian zone.

"Groundwater" resides below the water table at some depth below the surface, while "soil water" resides in tiny hollows between soil particles.

sediment or dissolved in surface runoff, groundwater, or soil water (water stored in the soil).

Riparian vegetation filters nutrients and toxic metals by trapping sediment particles to which they are attached. Phosphorus and nitrogen, two nutrients whose overabundance can harm river and lake systems, most frequently travel into these systems attached to sediment. Vegetation and microorganisms in a healthy riparian zone will consume many of the nutrients which are dissolved in surface runoff or in soil water. Woody riparian vegetation removes a significant amount of nitrogen from groundwater as well. Numerous studies indicate the effectiveness of riparian systems at removing nutrients and other chemicals, such as oils, insecticides, and herbicides.

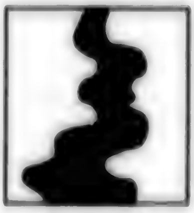
Temperature regulation



One of the ways in which riparian zones regulate a stream's temperature is shade. Overhanging and near-stream vegetation lowers water temperatures by blocking solar energy. Many fish species, including trout and salmon, are adapted to the resulting cool water. Trout, for example, will not survive in streams with average summer temperatures above 72° F. Removing vegetation can seriously affect those species' chances of surviving both because they are adapted to cool temperatures and because warmer water retains less dissolved oxygen than cool water.

Bank stabilization

A riparian zone stabilizes a stream's banks primarily by providing structure through its system of roots. The deep fluvial soils left by millennia of sediment deposition allow plants to send their roots deep into the earth. The resulting tangled mass of underground vegetation traps soils and protects them from the eroding forces of running water.



Food and habitat for aquatic communities

Vegetation protects not only soil, but offers important cover to fish and other aquatic species. They can hide under fallen logs or in the shade of an overhanging tree. The lush riparian vegetation is also a source of food as leaves and other debris fall into the stream.

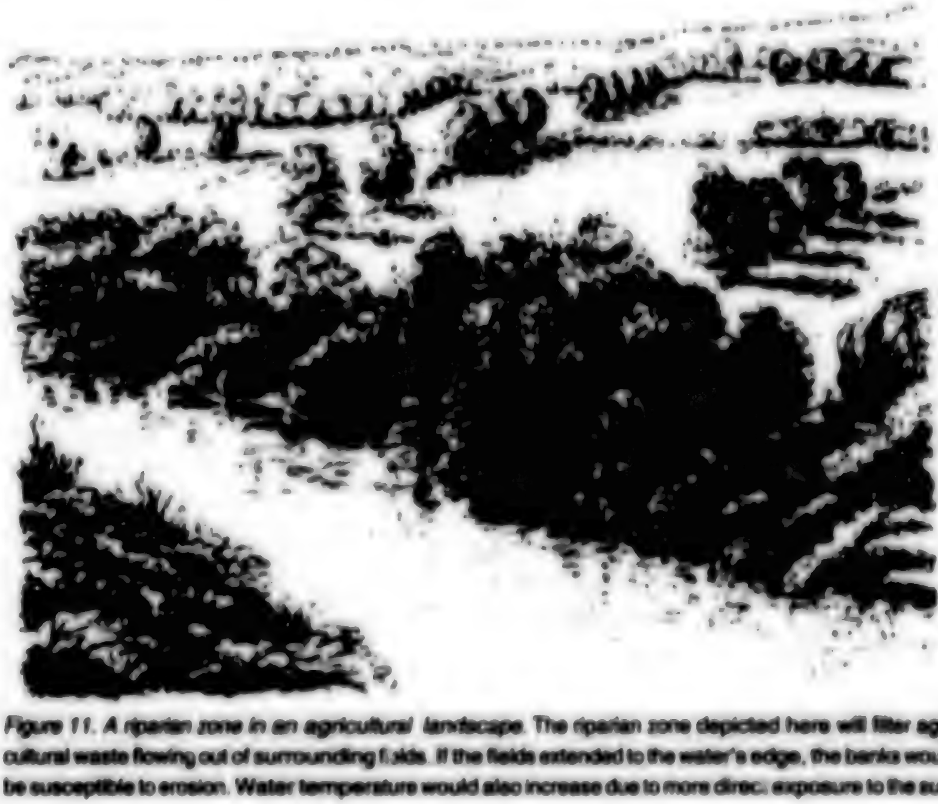


Figure 11. A riparian zone in an agricultural landscape. The riparian zone depicted here will filter agricultural waste flowing out of surrounding fields. If the fields extended to the water's edge, the banks would be susceptible to erosion. Water temperature would also increase due to more direct exposure to the sun.

Context and greenway functioning

A riparian zone's ability to perform its functions will depend heavily on:

- the status of upstream vegetation;
- land use of associated uplands; and
- the successional stage of the riparian zone itself.

A greenway's "context" refers to how it is situated in the landscape — the type and quality of surrounding land and its geographical relation to that land.

Status of upstream vegetation

If there is development along a stream, natural riparian zones downstream of that development will bear the brunt of stronger floods, no longer moderated by upstream vegetation. Similarly, increased amounts of sediments, nutrients, and toxins may overtax the remaining riparian zones and degrade them beyond their natural ability to restore themselves.

"Upstream" is uphill along, or parallel to, the stream while "upland" is uphill away from, or perpendicular to, the stream.

Land use of associated uplands

Activity in uplands also has enormous impact on riparian zones. Devegetation in these areas often increases the amount of water reaching the river system. If uplands have been converted to industrial, residential, or agricultural use, runoff from those sites can be laden with toxic and nutrient-rich waste. While riparian zones are effective filters of such waste, they can be overwhelmed.

Successional stage

The state of the riparian zone itself is also important. Mature forests are frequently at equilibrium, meaning that the amount of nutrients going into the system is equal to the amount coming out. Forests dominated by younger trees, however, will retain the many nutrients which the trees need to grow. In these cases, the effectiveness of riparian habitat at performing its filtering functions may be reduced compared to a riparian zone with younger trees.

Succession is the process of change from one habitat type to another (see Figure 12, page 26). A common example is a field reverting to forest. Shrubby, light-tolerant species will begin to take root around the edges. Gradually, shade-tolerant plants are able to grow under the original colonizers. Eventually, forest species will dominate. As older trees die and weaker ones blow down, small patches of light allow younger trees and shrubs to grow.

Protecting riparian functions with greenways

How do you design a greenway to protect riparian functions? Unfortunately, there is not a set answer which tells us exactly how wide a greenway needs to be or precisely what parts of the landscape to include. Ideally, a greenway should maintain the riparian corridor in as natural a state as possible. Using that broad statement as a guide, we can develop some notion of what should be included in a greenway.

How wide?

Efforts should concentrate on including the flood plain, its banks, and portions of the uplands in the greenway system on at least one side of the river and preferably both sides. It is during this journey from upland to river channel (see Figure 10 on page 23) that most of the filtering of sediments and chemicals takes place. A river's flood plain, bank system, and associated uplands generally increase in magnitude relative to the size of the river. Rather than seeking a universally applicable standard for greenway width, therefore, planners should base greenway design on

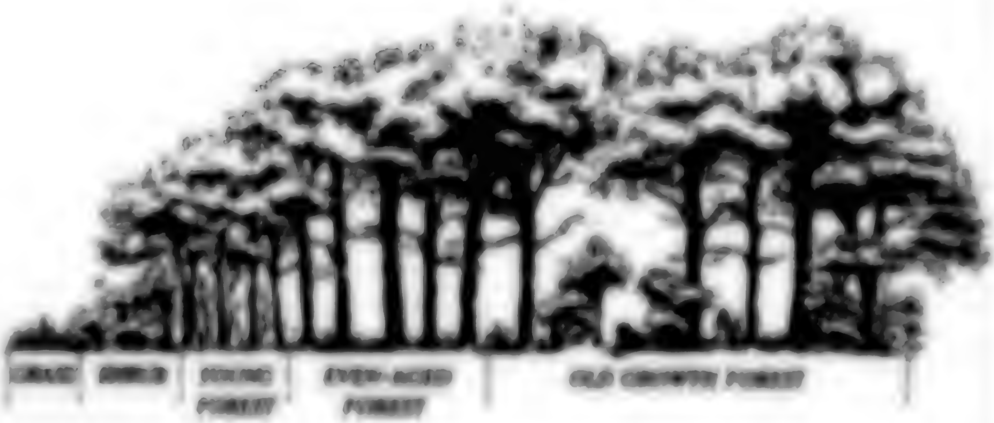


Figure 12. Successional stages of a forest. The illustration shows basic stages of succession from an open field to an old growth forest.

local conditions. Ideally, they should undertake a study which demonstrates how much sediment is entering the riparian zone, and how wide the zone needs to be to filter out an acceptable percentage of sediment and nutrients.

For example, a study in a coastal watershed in Maryland revealed that the first 250 feet of the riparian zone filtered out most of the sediment from runoff. Nearer the stream, the amount of filtering decreased (Karr and Schlosser, 1977). A similar study from North Carolina showed that more than fifty percent of sediment in runoff from agricultural fields was filtered in the first 300 feet of riparian vegetation (Lowrance, *et al.*, 1986). In both cases, the slope of the surrounding agricultural fields was relatively slight (0 - 7%). Riparian corridors will have to be wider where the source of runoff is large, slope is greater, human use more intense, or nothing is done in the fields to prevent erosion. These many variables make a study of the site very important.

What else?

Width should not be the only consideration — there are specific sites within the landscape which have direct bearing on riparian functioning. Intermittent tributaries (streams which form seasonally in response to increased rainfall or snow melt), gullies, and swales through which water reaches the stream should be included in a greenway because they are important components for the filtering and flow moderation functions of the riparian zone. Keeping these areas intact and vegetated with native species is important. Areas of aquifer recharge or discharge, such as wetlands, seasonally wet soils, or springs, are also critical. Identifying recharge and discharge sites generally requires a professional hydrologist and should be part of an initial site study.

Guidelines for maintaining riparian functions in a greenway

Make greenways continuous along the river.

Cover both sides of the waterway if possible.

Include in the greenway the river's flood plain, riparian forest, associated wetlands, intermittent tributaries, gullies, and swales.

Undertake a comprehensive study of the site's sediment and nutrient flow to establish how much is entering the riparian zone and how much it will need to filter. If this is not possible, rely on results from studies done at similar sites.

Base greenway width on comprehensive study of the site. Riparian greenways which neighbor intensive land uses such as clearcutting, monoculture, or shopping malls will need to be wide enough to absorb excess nutrients and toxins.

Maintain a band of natural vegetation along the stream bank to protect its temperature moderation function.

Avoid mowing streamside vegetation, as this practice will decrease its filtering effectiveness.

Supplement natural sediment trapping function of the greenway with retention basins or vegetated berms where necessary.

Supplement, *if necessary*, natural nutrient filtering functions of the greenway with a tree harvesting regime (derived in consultation with local forester and ecologist) to maximize nutrient uptake.

Sources of information:

Dunne, T. and L. B. Leopold. 1978. *Water in Environmental Planning*. New York: Freeman and Co.

U.S. Department of the Interior, National Park Service. 1988. *Riverwork Book*. Philadelphia: National Park Service.

Boulder, Colorado Case Study

The Rocky Mountains rise along the western side of Boulder, Colorado. It is hard to imagine that a community with that impressive a backdrop faces such environmental problems as declining wildlife populations and degraded water resources. But it does. The rise in Boulder's population, from 20,000 in 1950 to 90,000 today, has created increased pressures on the region's natural resources. In response, the city has established an extensive open space protection program.

The present emphasis of this program is to create a greenbelt around the city which would protect open space, provide recreational access, and produce a constraint against urban sprawl.

Although wildlife receives a lot of attention in Boulder's open space program, it is also useful as a case study for its emphasis on water resources. Specifically, Boulder is concentrating on three areas of water resource protection:

- riparian corridors in rangeland;
- restoring Boulder Creek (which runs through the city); and
- flood control.

Boulder imposes guidelines on ranchers who lease the city's open space for rangeland. Grazing practices must mimic patterns of the plain's original occupants (including bison) to prevent overgrazing and discourage exotic species. Changes in grazing patterns to those of domesticated cattle has favored weeds such as Canadian thistle, napweed, and cheatgrass over native shortgrass prairie species. In order to protect water resources, livestock are not allowed near riparian vegetation or the steep slopes associated with streams. Livestock can be a major source of streambank erosion and streambed disturbance if left to approach and cross streams regularly.

Within the city, the Boulder Creek Greenway is another focus of the open space program. Development has degraded riparian and aquatic habitat along Boulder Creek and seriously altered flow by restricting its channel. The greenway includes structures designed to reproduce the natural pattern of riffles and pools. The city has also widened and deepened the stream so it will flow more quickly and carry more sediment. Recreation, once uncontrolled and damaging, is now oriented along paved bicycle paths set back from the stream's banks. Restoration of Boulder Creek has increased trout populations and created wildlife habitat.

Along another part of Boulder Creek, the city has targeted flood control. In this area, the city has purchased forty-seven buildings. With the buildings gone, the city will lower the flood plain in that area by two to three feet thereby increasing its capacity to hold water during a flood. Most of the time, of course, the stream will remain in its banks and the flood plain will serve as a recreation area.

Outside of the city, Boulder County has a riparian restoration project underway along Boulder Creek. Changes in the stream have made it more shallow, raising temperature and increasing algal populations. The result is a rise in the stream's pH to the point where ammonia from a sewage treatment plant rapidly converts to a more toxic form.

Rather than make expensive improvements to their treatment plant, the county restored altered portions of the creek by deepening its channel, increasing flow, and creating riffles and pools. Revegetation along the banks produces shade, stabilizes streambanks and provides habitat and food to the aquatic community. The impact has been an overall reduction in temperature, pH, and toxic ammonia.

Ammonia is not the only problem in the creek; nutrients from surrounding farmland also pollutes it. In an effort to tackle that problem, the county has established a program to create wetlands along the stream. These wetlands should filter out many excess sediments and nutrients and help restore the creek.

Through considered design, the city and county of Boulder have used greenways to improve water quality while providing recreational opportunities and wildlife habitat. Not all of the land is publicly owned; some of the restoration projects occur on land protected by easements and the county is encouraging private landowners to manage their riparian areas in a similar way. Protecting and restoring riparian zones is one part of a much larger vision in Boulder County. The county and a local conservation group, the Boulder County Nature Association are working together and with private landowners and federal agencies to maintain migration routes and other important habitat.

CHAPTER IV

Greenway Design and Management

Chapter III dealt with how to design greenways to fulfill specific ecological functions such as habitat, conduit or filtering. This section covers a more general set of issues (not necessarily unique to greenways) of which greenway designers and managers should be aware:

- designing and managing for change;
- exotic plant and animal species;
- the impact of roads;
- interactions between people and greenways; and
- maintaining ecological health within the greenway.

Addressing each of these topics involves both design and management. It is therefore worth considering what those two terms mean and how they are related. Although the term design has many connotations, we are most interested in design as it relates to greenway shape, composition, and context. As seen in the previous chapter, meeting ecological goals requires careful consideration of how wide the greenway is, what parts of the landscape it connects, and what kind of habitats are included. These are design considerations.

Design also has an important aesthetic component. Diana Balmori, a contributing author in *Ecology of Greenways*, says of design: "It solves the functions and tries to go beyond to an aesthetic dimension, attempting to make something beautiful, and tries to ground that form into something meaningful to the society that creates it."

Management picks up where design leaves off. Managers ensure that the greenway continues to meet the objectives laid out in the design process. For example, one task might be to maintain the quality of habitat through such measures as controlling exotic species, reducing human impact through trail maintenance, or replanting to native vegetation.

Designing and managing for change

Natural systems are in constant flux — they are always changing. The Greek philosopher Heraclites said that you can never step in the same river twice. He could have said the same for a field, tundra, forest, or desert. But that is easy to forget because we rarely see change occur. Nonetheless, it is critical to allow natural change to take place in protected areas because it is an inherent aspect of nature. There are both design and management considerations which can help achieve that goal.

Designing for change

The very idea of planning for change may seem contradictory. How can we possibly plan for something if we do not know what it will be? Greenway designers can respond to uncertainty and anticipate the long-term needs of the natural community by:

- protecting secondary habitat;
- identifying and protecting areas of rich biotic diversity; and
- including a diversity of habitats within the greenway.

Secondary habitat — Secondary habitat refers to areas which plants and animals need occasionally. For example, a fire could destroy part of a greenway and prevent animals from using it as a movement corridor until vegetation grows back. In a landscape where that corridor is the only way for wildlife to move between important habitats, the fire could be devastating. Guarding against such an event requires including more than one movement corridor in a greenway system so if one is temporarily unusable, wildlife can use another (See Figure 13).

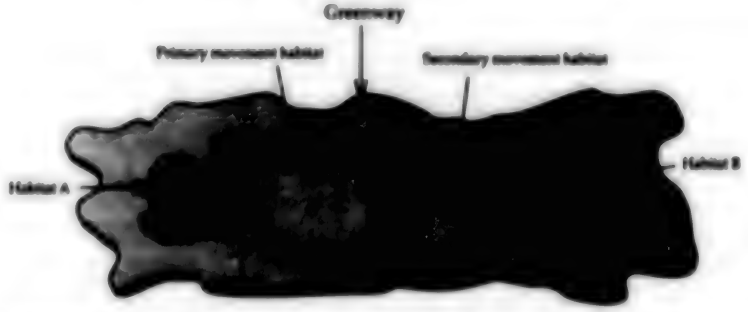


Figure 13. Secondary movement habitat within a greenway. Animals moving from Habitat A to Habitat B may prefer the primary movement habitat because it is wider. In the event of a disturbance, however, this route may become unusable. Without an alternate route (the secondary movement habitat), Habitats A and B will be isolated from each other.

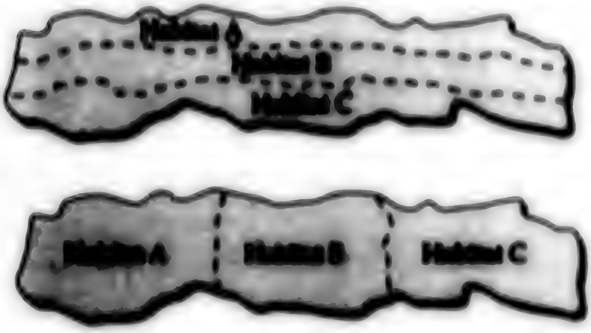


Figure 14. Habitat distribution along a greenway. When possible, habitat should be contiguous along the length of a greenway (top figure) rather than across it (bottom).

Centers of diversity — As change occurs, some new species will arrive and others will leave. We do not know which ones and therefore cannot plan for specific future conditions. We can assume, though, that a patch of land which supports a rich diversity of species now will probably continue to do so in the future. Concentrating our efforts on preserving areas in the landscape which are currently centers for high diversity will help ensure that a greenway will continue to protect the range of species adapted to contemporary conditions, whatever they might be.

A "gradient" is a gradual change in environmental conditions due to transitions in the landscape, such as an increase in precipitation resulting from an increase in altitude.

Diversity of habitats — Another way to manage for change is to include a high diversity of habitats in a greenway. Habitat may change very dramatically over a small distance. This is particularly true where physical characteristics in the landscape cause gradients in environmental conditions. An example of an environmental gradient is altitude. Temperatures drop as altitude increases; soils often become thinner; average wind velocity rises; and precipitation usually increases. In the northern hemisphere, conditions at the top of mountains resemble lower altitude habitats farther to the north. Including a mountainside or other gradient in a greenway, therefore, will add greatly to its diversity of habitats.

For a greenway to act as a conduit for plants and animals, habitats should be as continuous along its length as possible. Patterns of habitat diversity, therefore, should be oriented along the greenway, rather than across it (see Figure 14), to maintain connectivity. In the case of the mountainside, a greenway which goes up its slope rather than along its valley may not act as an effective movement corridor.

Managing for change

Including secondary habitat, centers of diversity, and diverse habitats in a greenway are all design considerations: they involve creating greenway boundaries to meet certain goals. Once a greenway is created, there are management strategies which also address the issue of maintaining change as part of the greenway's ecology.

Some plants and animals are adapted to events which we consider disasters, such as floods or fires. From nature's point of view, removing such events from a landscape may be the real disaster. Greenways, many of which are in or near urban centers, will exist largely in human-dominated landscapes. We have taken great pains to remove floods, fires, and other natural disturbances from our cities and towns. Thus, greenway managers may not only have to plan for unforeseen change but they may also have to ensure that changes that were once part of the natural landscape continue to occur.

An example of change is fire. Fire is an important part of many landscapes, such as western forests and midwestern prairies. Removing fire from ecosystems where it occurs naturally disrupts the processes to which plants and animals are adapted. For example, the cones of some trees open up and disperse their seeds only when subjected to the extreme heat of a forest fire. Without fire, it is more difficult for those tree species to reproduce themselves. There are also many plants and animals which are adapted to take advantage of conditions which prevail after a forest fire. One such plant, fireweed, gets its name from its dependence upon fire. In ecosystems where plants and animals are adapted to periodic fires, greenway managers may want to initiate a prescribed burning routine which mimics natural occurrence of fire.

Adaptive management — Once we accept that change is an inherent part of nature, we must adopt management techniques which reflect that reality. One such technique is called adaptive management. In this approach, managers monitor the greenway to understand what changes are taking place, which management policies are improving ecological functioning, and which are not. By responding to new information from monitoring efforts, management becomes a dynamic process of adapting to ecological and cultural changes. Areas which are facing heavy recreational impact can be closed off or restricted to walkers. Scientists may discover that animals only use part of the greenway as a corridor, allowing more area to be opened up to the public.

Guidelines related to designing and managing for change

Design a greenway as part of a larger network of corridors to provide secondary habitat.

Include a variety of habitats such as different soil types and wetlands.

Design the greenway to include ecological gradients such as elevation change.

Sources of Information:

It may be necessary to consult with ecologists with an understanding of the local landscape to identify areas of diversity or secondary habitat. Certainly, such experts should be consulted before undertaking such active management measures as prescribed burning or herbicidal soil clearing.

McHarg, I. L. 1969. *Design with Nature*. Garden City, NY: Doubleday/Natural History Press.

The Conservation Fund will publish a guide, edited by Loring Schwarz and written by Charles Flink and Robert Searns, on greenway planning, design, implementation, and management to be released by Island Press (Washington, DC) and available in the spring of 1993.

Southeastern Wisconsin Regional Planning Commission Case Study

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has developed a plan designed to maintain the ecological health of its region through the protection of important environmental corridors. SEWRPC has planning jurisdiction over seven counties and 2700 square miles. Most of the area is agricultural except Milwaukee and isolated hardwood forests. A large part of SEWRPC's work is devoted to protecting environmental corridors of regional significance. SEWRPC's emphasis on corridors is based largely on work done by Phillip Lewis from the University of Wisconsin (Madison). After mapping the state's important natural resources, Lewis realized that most of them are concentrated linearly along rivers and ridges.

Greenways in Milwaukee County protect three major rivers. Ranging from 1,000 feet to a mile wide, these greenways fulfill many of the functions discussed in this handbook — providing habitat, protecting water quality, controlling floods, and creating recreational opportunities. In the less urbanized areas, riparian greenways filter nutrients and sediments from agricultural runoff. They also provide valuable movement corridors for wildlife and protect remaining woods.

Although this case study addresses wildlife and water resource issues, the primary reason for including it is to illustrate an example of designing and planning greenways to improve the ecological health of an entire region. SEWRPC identifies and prioritizes environment corridors with the aid of a geographic information system (GIS). The GIS stores maps of land use and various important natural resources such as vegetative cover, wildlife habitat, soil type, and hydrology.

Using a system which attributes points to each resource type, SEWRPC is able to create maps which identify areas where a combination of important resources reside. Areas which SEWRPC defines as significant are those with resources that total ten or more points. When such areas are corridors, as they often are, they undergo another round of prioritizing based on area, length, and width. Primary environment corridors are those of at least 400 acres, two miles long, and 200 feet wide. Secondary environment corridors are smaller, shorter, and more narrow. State and county conservation efforts focus on primary corridors and SEWRPC refers secondary corridors to the local level.

A primary focus of this approach is to maintain connectivity throughout the landscape with high quality corridors. Occasionally, a small area of land which did not receive enough natural resource points to merit consideration separates two high quality corridors. SEWRPC can connect the two patches if the distance is short enough. Justification is based on the size of the smaller patch — a patch of 640 acres or more justifies a connecting zone of one half of a mile while a 100-acre patch warrants a connecting zone of one sixth of a mile. The idea behind this is that small patches of land harbor small species such as squirrels and mice which are less likely to travel long distances. A larger patch will contain deer or fox that need more land and will travel farther to find it.

Of the 467 square miles of primary corridors, local, state, and county governments own 147. Local zoning and various local, county, federal, and state regulations protect another 202 square miles which are in private hands. Proposed development such as sewer extensions undergo strict review to ensure they do not threaten primary environment corridors. Thus much of the region's important natural resources have some form of protection. By identifying areas of critical natural significance (which often turn out to be corridors) and establishing a system to extend various degrees of protection, Wisconsin has created a method for maintaining the ecological health of its landscape.

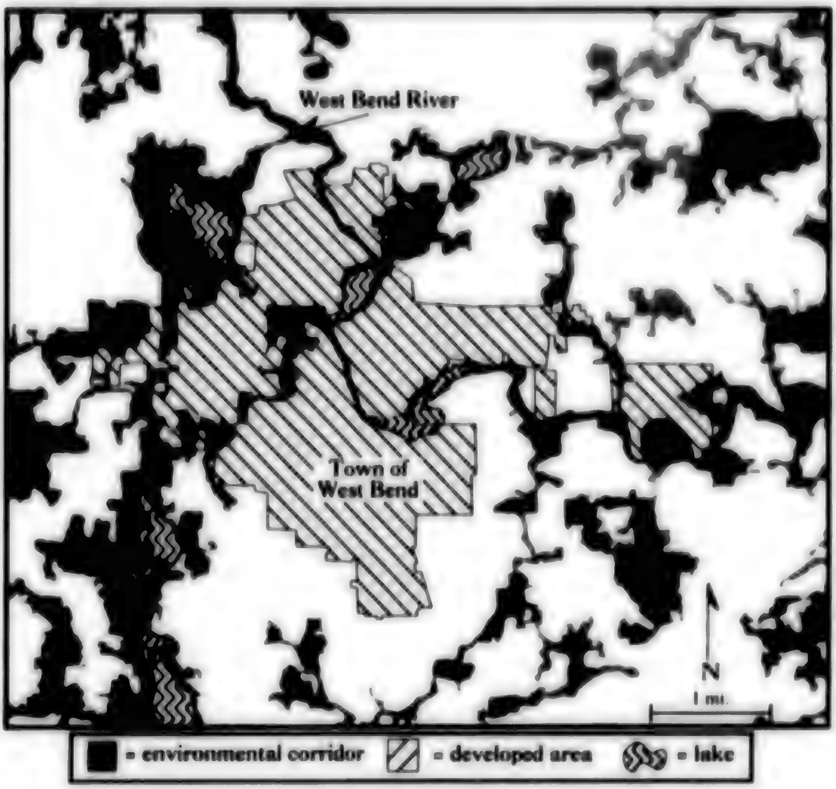


Figure 15. Map of Environmental Corridors, West Bend, Wisconsin.

Exotic species

Designing and managing a greenway to account for and accommodate change is a challenge made greater because some changes are ecologically desirable while others are not. Change that is naturally a part of the ecosystem should be encouraged but change resulting from human intervention should be avoided. Among the more detrimental changes that can occur is the invasion of exotic species.

Most exotic species depend upon people to survive — we bring them, intentionally or accidentally, to their new destination and we create conditions which favor exotic species by altering the landscape. A healthy landscape in its natural condition can usually ward off exotic species. Where native species are not adapted to new, human-generated conditions, exotic species may be able to replace them.

Causes of Invasions

Greenways, especially ones in urban or suburban landscapes, will be susceptible to invasion by non-native species. This is due largely to human disturbance either within the greenway or in the surrounding land. Heavy recreational use can create disturbance within a greenway. Surrounding land can influence a greenway primarily through edge effects. Opportunistic plants and animals thrive in disturbed lands, competing with original inhabitants for food and shelter. Exotic species often thrive in their new environment because they have no predators or are more adapted to human landscapes.

Dangers of Invasions

While exotic species pose a threat to greenways, the threat to other protected areas such as nature preserves may be even more serious. If a greenway fulfills its role as a conduit, it can provide exotic species access to important natural areas. Exotic species threaten biodiversity in protected areas because they can dominate their new landscapes to the exclusion of many native species.

Based on the understanding that exotic species can be damaging to an ecosystem, one of the design and management priorities for a greenway project should be to maintain the native mix of species. Preventing invasion, or eradicating unwanted species is likely to be site-specific, depending greatly on the species involved.

Guidelines to prevent biotic invasions

Replant disturbed sites with native species.

Generally, avoid the temptation of planting exotic species even though they may have beneficial qualities such as erosion control or high-quality food source.

Engage in active management schemes such as intentional burning where these conditions are favorable to native plant species.

Always manage a greenway to benefit native species. This may require consultation with local botanists who study local plant and animal species and their needs.

Sources of information:

Local landscape architects generally know which plant species are exotic to the area and can be an excellent source of information on how to manage your greenway with native plants.

Elton, C. S. 1958. *The Ecology of Invasions by Animals and Plants*. London: Methuen.

Mooney, H. A. and J. A. Drake, eds. 1986. *Ecology of biological invasions of North America and Hawaii*. New York: Springer-Verlag.

The impact of roads

Although roads will provide many people access to greenways, they present a unique set of design and management problems. Due to effects of edge and fragmentation, a road affects the landscape well beyond its pavement's edge. Two major impacts that a road can have on its surrounding landscape include:

- providing dispersal routes for unwanted species; and
- constituting dispersal barriers for native species.

Dispersal routes for unwanted species

Cleared areas along roads usually represent disturbances to native habitat. Weedy species benefit from these conditions and may migrate along roads to colonize areas previously out of their reach. In some cases, however, highway medians and other clearings may represent remnant patches of native habitat. This is particularly true in the midwest where cultivated fields have replaced much of the native prairie. Conservationists may want to cooperate with highway departments to implement a management plan that favors native species. Many states restrict mowing in highway medians, for example, to allow native wildflowers to grow.

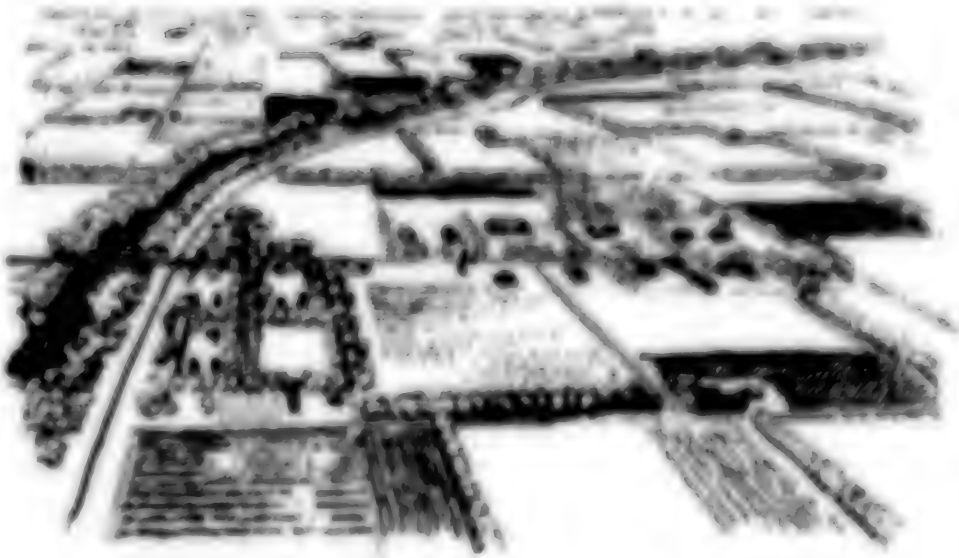


Figure 18. A riverside greenway. A greenway along a river, such as this one, is not likely to intersect as many roads as one created through the mosaic of fields.

Dispersal barriers for native species

Roads frequently pose barriers to species which would normally move throughout the landscape. Some species – desert rodents and even black bears – rarely cross a road. Road kills cause huge losses in some species. American motorists daily kill more than a million vertebrates (Lalo, 1987). Proper management, however, can reduce roadkill. In an effort to decrease highway mortality of migrating mule deer, the Colorado Division of Highways built a tunnel under Interstate 70 near Vail. Fences prevent deer from crossing the interstate and channel hundreds of them into the tunnel and safely under the highway. (See Santa Monica Mountains case study on pages 20 and 21.)

Guidelines related to roads

- Strike a balance between siting greenways near roads to provide adequate public access and keeping the number of places where roads bisect the greenway to a minimum to reduce detrimental impacts associated with roads.
- Work closely with highway departments to coordinate land use management.

Interactions between people and greenways

It is easy to fall into the assumption that everything we do harms the environment. Our relationship with nature is complex and it is unfair to over-emphasize our harmful impacts. Indeed, greenways, and their popularity, bespeak a very different tradition. Greenways represent our desire to foster a healthy and responsible attitude toward nature. Two ways in which greenways can help achieve that goal is through providing opportunities for recreation and public education.

Figure 17. Children participate in an "Environmental Cleanup Day." Greenways offer people the opportunity to get involved in a range of environmental activities such as this trash pick-up event.

Recreation

Greenways are well suited for outdoor recreation. Their linear shape corresponds to trails and rivers. Since greenways use land efficiently, and do not necessarily require strict protection, they can fit into many urban and suburban landscapes where access to natural spaces is limited. Heavy recreational use, while socially beneficial, can produce short-term ecological damage in the following ways:

- compacting soil;
- increasing erosion;
- trampling and mutilation of vegetation;
- disturbing wildlife; and
- introducing non-native species.

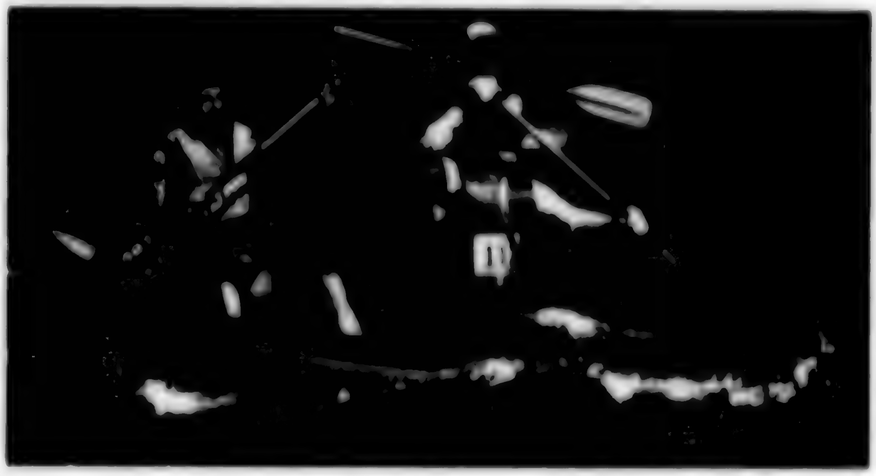


Figure 18. The annual "Gap to Gap Relay" on the Yakima River, Washington. Recreation is a traditional use of greenways and a basis for public support.

Soil compaction — The weight of walkers and runners compacts the soil along a trail. Once compacted, soil can no longer hold as much water or support as much life, such as roots and microorganisms. Generally, compaction is limited to the immediate vicinity of a trail.

Erosion — Compaction and loss of vegetation often leads to erosion because rain which would have soaked into the ground instead runs over its surface, building velocity and carrying sediment. Erosion also often occurs where trails traverse steep slopes or meet the water's edge.

Damage to vegetation — Trampling and mutilation of vegetation is most common at campsites and other areas of intense use such as scenic overlooks. Small saplings, twigs, and near-surface roots get damaged. People sometimes carve initials and other graffiti into mature trees.

Disruption of wildlife — Although narrow, trails can produce effects associated with fragmentation. While not as damaging as roads or land conversion, trails can increase edge habitat, bringing edge species into contact with interior ones. Trails offer access to people, whose presence wildlife may learn to avoid, further reducing the amount of land species can utilize.

Introduction of non-native species — Disturbed environments, such as trails and campsites, favor opportunistic exotic species over native ones. Hikers, bikers, and horses offer a mechanism for these species to reach disturbed areas.

Avoiding and controlling use — Minimizing effects of recreation can follow two approaches: avoiding sensitive areas and controlling use of trails and other facilities. A natural resource inventory identifies sensitive areas. Wetlands, steep slopes, thin soils, and river- and streambanks are all examples of conditions which are not appropriate for heavy recreational use. Siting trails along the edge of forests reduces fragmentation and provides diverse views.

Physical constructions or signs can control use where it is unavoidable or desirable. For example, wetlands are among the most interesting aspects of the environment but sensitive to human use. They afford wonderful educational opportunities to see rare plants and animals. Wooden platforms, bridges, and causeways protect the habitat while allowing people a view. Greenway planners should also consult design manuals which describe different trail materials such as crushed native stone or pine needles.

Some types of use are more damaging than others. Given similar numbers of users, walking is the most benign use while motorized all-terrain vehicles tend to be the most destructive. Between the two extremes lie horseback riding and mountainbiking. Not all these uses are socially compatible, although this will depend on the region. Whatever combination of uses are socially and ecologically acceptable, it is important that they be restricted to planned and maintained trails. It is often tempting to cut one's own path to get a view or to walk alongside a friend.

Public education

Environmental — Our interactions with the environment are not one-way. We may have an impact on nature, but it also has an impact on us. Greenway designers can capitalize on this by placing trails and signs to educate the public. Education extends a greenway's conservation potential beyond such direct benefits as combating fragmentation or protecting riparian functions. The attention a greenway focuses on a community's river, for example, can inspire residents to form a citizen monitoring group. Keeping a close watch on a river's water quality allows a community to pinpoint sources of pollution. Through disseminating information, organizing, and lobbying, such efforts lead to cleaner waters and a healthier environment.

Cultural — Cultural heritage can be part of a greenway along with natural heritage. Old homesteads, locks, mills, or fishing weirs attract people's attention and interest. Emphasizing such forms of development, which often relied greatly on the natural landscape, highlights a community's past and its connection with the environment. People's natural pride in their heritage will make the greenway a fixture in the community. Signs and educational programs can play a major role in enhancing public awareness and support.

Guidelines related to interactions between people and greenways

Base trail and facility location on the sensitivity of greenway habitats, and the type and intensity of use.

Avoid wet or shallow soil and steep slopes to minimise soil erosion and disruption of vegetation from recreational use.

Utilise trail surfacing materials which are permeable and do not compound drainage and erosion problems.

Minimise trail width in forest interior to minimise its impact.

Avoid building trails that run along the length of greenways designed to be movement corridors or habitat for wildlife; instead create spurs branching off from a main trail outside the corridor or habitat to provide access to viewing points.

Locate areas of potential intensive use along the greenway's boundaries.

Expand a visitor's understanding of nature to include the whole landscape by integrating areas of cultural significance or scenic vistas.

Provide low-impact pathways through the greenway's various habitats and geological or cultural features.

Sources of information:

Stokes, S. N., A. E. Watson, G. P. Keller and J. T. Keller. 1989. *Saving America's Countryside: A guide to rural conservation*. Baltimore: Johns Hopkins University Press.

Proudman, R.D. and R. Rajala. 1984. *AMC Field Guide to Trail Building and Maintenance*. 2nd edition. Boston: American Mountaineering Club.

Maintaining ecological health

Bolstering the ecological health of a landscape is the major reason for designing and managing greenways with ecological functions in mind. We may have some vague notion of what ecological health means, but faced with complexities like exotic species or successional change, what appears healthy may not be. A greenway can be green, yet not support the full diversity of species native to the area. Conversely, a greenway may be dry and sparsely populated, yet represent a region's natural vegetative cover and wildlife.

The appearance of ecological health is site- and function-specific — so how do we know what is natural and how do we ensure that natural conditions prevail? In some cases, where development has dramatically changed the environment, it may not be possible to determine what "natural" means. But, when some remnant natural space exists, it can serve as a guide to how the ecosystem should function.

Careful study of the natural sites leads to understanding of what "ecological health" means for the altered site. The study should concentrate on the number of species, what species are represented (composition should match natural balances of plant-, insect-, and meat-eating species), and the number and health of individuals. This technique measures a site's biological integrity against a similar one from its own region. It does not favor increasing diversity or populations to match popular notions of healthy ecosystems, rather it reflects natural balances.

Guidelines for [illegible]

- Determine [illegible]
- Identify a site [illegible] basis for [illegible]

Conclusion

Greenways offer conservationists an opportunity to translate public support for locally oriented land protection into long-term ecological gain in a feasible and cost-effective way. While applying the concept of ecological functioning to greenway design and management helps us to fulfill their potential as protected areas, it should also teach us that greenways alone are not enough. Just as different parts of the landscape fulfill different ecological roles, greenways have different ecological potentials from other types of protected land.

By the same token, a greenway may not always be beneficial. Greenways, especially those designed to connect existing protected areas, require careful scrutiny to ensure that they do not promote unwanted movement, such as exotic species or fire, between nature reserves. Greenways should protect *natural* linkages in the landscape, not create artificial ones. It is essential that, whenever possible, greenway projects be preceded by thorough studies of the landscape.

As the vitality of Britain's hedgerows suggests, letting nature reign, even in narrow strips of land, can be greatly beneficial to a landscape. While the primary goal of land conservation remains protecting native ecosystems at a scale which will ensure their long-term survival, every little bit of green space is important. Considering greenways in an ecological light indicates that relatively little land, when designed and managed with regard to natural process, can produce a lot of environmental return.

In producing environmental return, greenways can also provide economic benefit. Another publication by the National Park Service, *Economic Impacts of Protecting Rivers, Trails, and Greenway Corridors*, goes into great depth on how greenways bring business into a community and provide natural alternatives to expensive projects such as water filtration and flood control. We hope that these two publications will help increase understanding and appreciation of greenways and foster support, enthusiasm, and an ever-expanding network of these wonderful places.

Figure 19. A field trip into the wetlands of Kandiyohi County, Minnesota. Environmental education heightens awareness of the connection between ecological and community health.

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National Park Service: Rivers, Trails, & Conservation Assistance

Citizen groups and private organizations, and federal, state, or local government agencies are eligible for advice and technical assistance through the Rivers, Trails, and Conservation Assistance Program.

- Projects may vary from one-time consultations to extended studies.
- Projects are encouraged in urban as well as rural and natural areas.
- All projects selected for assistance must involve significant resources and demonstrated public support and commitment.
- Program funding is on a fiscal year basis.

For more information contact the appropriate National Park Service Regional Office.

Quebec-Labrador Foundation's Atlantic Center for the Environment

The Atlantic Center for the Environment, part of the Quebec-Labrador Foundation, is a non-profit educational and environmental organization incorporated in both the United States and Canada. For nearly thirty years, the Atlantic Center has worked to promote local leadership and to conserve the natural and cultural resources of rural communities in the Atlantic Region (northern New England and eastern Canada) through cooperative education and research projects. The Atlantic Center enjoys a growing international program as well, with strong ties to conservation nonprofits in central and western Europe and Latin America and the Caribbean.

This handbook is a product of the Atlantic Center's Technical Assistance Center, part of their Stewardship Program. The goal of the Stewardship Program is to transform environmental awareness into action at the community level. To that end, the Technical Assistance Center provides support to local nonprofits such as land trusts and watershed councils. Technical assistance projects involve introducing people to current trends in ecology and technology and helping them gain access to these advances. Projects include publications, mapping, organizational assistance, and computer training.

For more information, contact the Atlantic Center
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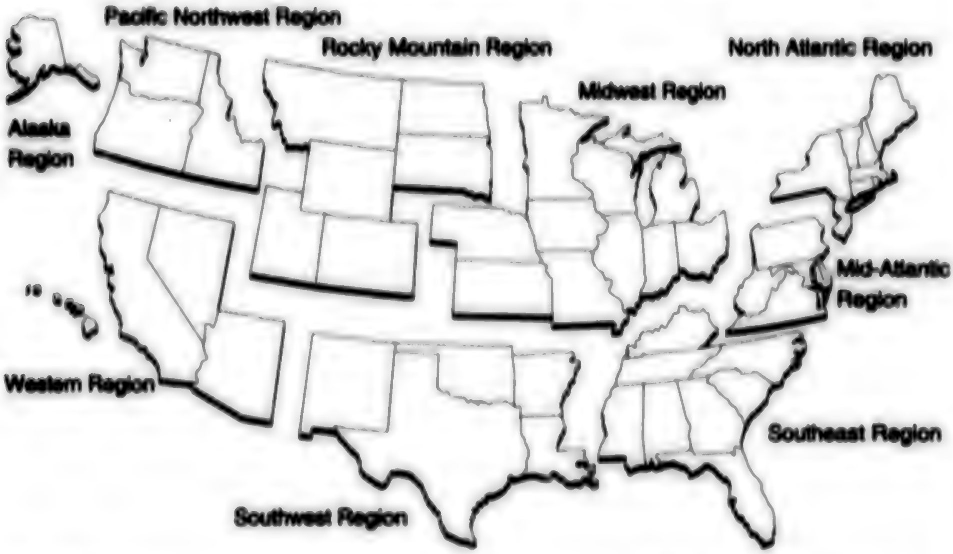

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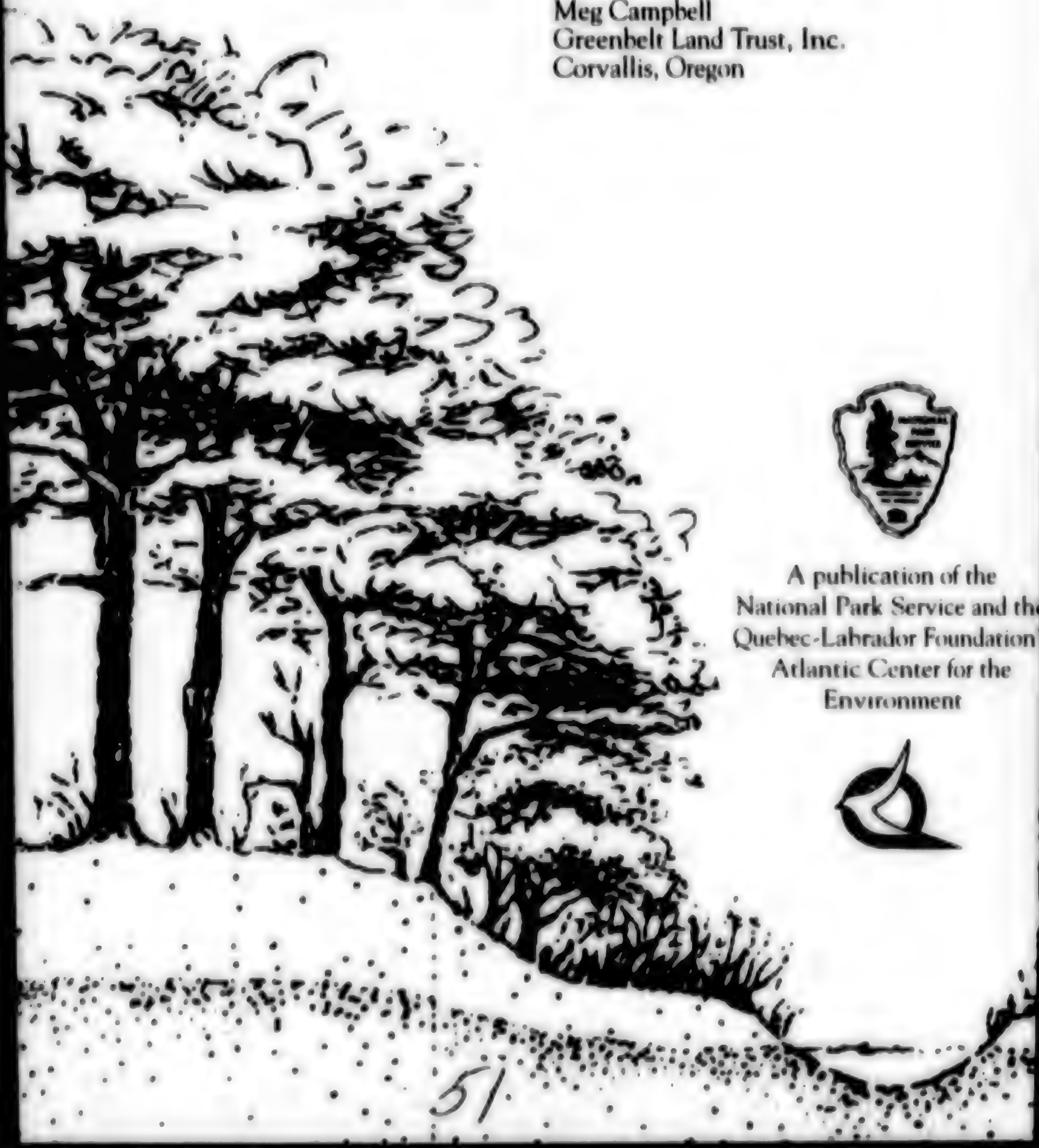
"You have a very useful and needed publication; the concepts, guidelines and graphics presented will be important tools in counter-balancing the various demands placed on greenways and in encouraging the creation of more ecological greenways."

Loring Schwartz
The Conservation Fund

"I believe this handbook will be extremely valuable to land trusts such as ours, which is a young organization. Public agencies such as city and county parks departments will certainly find it helpful as well. The script is clear, well within the understanding of most people regarding ecology. The ideas seem clearly transferrable to design and management plans. For us, it is very timely and useful."

Meg Campbell
Greenbelt Land Trust, Inc.
Corvallis, Oregon



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